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Both sections effectively drained all subsurface water at the site through an unusually wet winter and spring.

Only minor difficulties were encountered in the construction of the two-layer system which could probably have been eliminated by a modification in the grading of the filter element.

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HIGHWAY RESEARCH REPORT

PERFORMANCE OF AN ASPHALT TREATED DRAINAGE BLANKET IN A FLEXIBLE PAV[illegible]CTION

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STATE OF CALIFORNIA

BUSINESS & TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

December, 1969

Interim Report
M&R No. 632618

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

PERFORMANCE

of an

ASPHALT-TREATED DRAINAGE BLANKET

in a

FLEXIBLE PAVEMENT SECTION

TRAVIS SMITH
Principal Investigator

RAYMOND FORSYTH and WESLEY GRAY
Co-investigators

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

Travis Smith
Raymond Forsyth
Wesley Gray

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ABSTRACT: This paper presents the results of a field evaluation of a two-layer highway drainage system on Road 299 between Arcata and Willow Creek in the northern coastal region of California.

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Both sections effectively drained all subsurface water at the site through an unusually wet winter and spring.

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KEY WORDS: Permeability, roadway drainage, drainage filter, Asphalt stabilization, drainage capacity.

Travis Smith
Raymond Forsyth
Wesley Gray

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PERFORMANCE OF AN ASPHALT TREATED DRAINAGE BLANKET IN A FLEXIBLE PAVEMENT SECTION

By

Travis Smith[1], Raymond Forsyth[2], and Wesley Gray[3]

Introduction

The importance of surface and subsurface drainage of the highway structural section has been recognized since construction of the early Roman roads. In an attempt to alleviate unsatisfactory subsurface water conditions, the early British road builder, McAdam, utilized a layer of open-graded stone within the pavement section.

The effects of the accumulation of water due to surface infiltration, a high water table or capillary rise has been well documented in the literature. Some of the more important manifestations of this problem in a flexible pavement section include (1) negation of the load spreading characteristics of elements of the structural section, (2) asphalt stripping and pumping of fines into the intimate part of asphalt concrete mix resulting in premature hardening, (3) excessive transient deflection resulting in early fatigue cracking, (4) contamination of the base and subbase layers by pumped fines

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resulting in lowered stability, (5) uplift of the surfacing.

The problem of providing a drainage layer sufficiently permeable to remove excess water quickly and still fine enough to preclude contamination and thus clogging by fines was largely solved with the development of Terzaghi's[1] filter criteria with subsequent modification by others.[2][3][4] This practice has been developed to a high degree in earth-dam construction where, in some instances, up to 5 layers of graded materials are employed for filtration and drainage.

The use of a separate filtration layer for roadway structural section drainage has, however, failed to gain wide acceptance due presumably to cost, complexity, and the difficulties inherent in placing and compacting the open-graded drainage layer. Another factor, undoubtedly, has been a failure to recognize and take into account hydraulic characteristics of varying gradations of permeable material. The California Division of Highways in common with many other highway agencies has, in the past, sought to solve the problem of subsurface drainage with a single drainage layer. Table 1 shows the trends in California specifications for permeable materials through the years. Before 1945, subsurface drainage consisted of a coarse grading of from one to six inches in size. This material was used for "French drains" and produced a high degree of permeability. These drains were initially successful, but in many instances they became clogged and thus ineffective within the design life of the roadway. In 1945, in order to achieve some degree of filtration, a graded aggregate from 2½ inches maximum down to the No. 200 sieve was specified. In 1954, three classes of permeable material were established. Class A was fine-graded material 3/4 inch and finer in size, Class B was graded from 1½ inch maximum and Class C from 2½ inches maximum. These grading requirements resulted in the use of materials which were undoubtedly only slightly more permeable than the water bearing native soils they were to drain. Recognizing the critical effect of gradation on drainage capacity, a rather restrictive permeable grading specification was included in the 1960 specifications. The difficulty in attaining this specification using conventional aggregate processing equipment resulted in a relatively expensive product. In 1964, based upon the results of a large number of laboratory permeability tests, a new series of gradings were adopted. These gradings were two to three times as permeable as the 1960 material and at the same time somewhat easier to manufacture since the gradation consisted simply of a standard undersanded concrete aggregate. This undersanded permeable material is still included in the standard specifications and is probably as effective a "universal" permeable material as is practically possible. Even so, natural segregation resulting from undersanding has resulted in wide variations in permeability.

One of the early proponents of two-layer subsurface drains in highway construction was Mr. W. R. Lovering who, as a

District Materials Engineer for the California Division of Highways, had many occasions to observe the results of inadequate or clogged drains through the wet cuts common to northwestern California. In 1960, Mr. Lovering made specific proposals for the employment of two-layer subdrainage systems in highways.(5) Recognizing the difficulties inherent in the construction of a firm working table utilizing the one sized aggregates necessary for the drainage layer, Lovering and Cedergren proposed in 1962, the use of a lean asphalt mix of coarse one size material for the drainage layer.(6) This paper reported the effect on permeability of treatment of open-graded aggregate with 2% asphalt. These data revealed that the presence of asphalt binder did not significantly lower the permeability of the drainage layer. It was also pointed out that while the cost per ton of an asphalt treated mix would be higher than the cost of untreated aggregate, an overall reduction in cost was possible as a result of the thinner drainage layer resulting from the greatly increased permeability. This was convincingly demonstrated with specific design examples in the concluding section of the paper.

<u>The Kneeland Road Project</u>

In 1967, a two-layer graded structural section drain utilizing asphalt treated drain rock was placed in an experimental project in Humboldt County in the north coastal area of California. The results of this project were reported in some detail by Cedergren and Lovering in 1968.(7) The soils in this area of heavy rainfall (40 in. to 80 in. per year) consist of faulted and folded sedimentary deposits. Numerous spring areas along existing cut bank faces can be observed during the winter and spring seasons. The original pavement which had been built with a drainage blanket to control subsurface seepage failed due to inadequate drainage capacity. The two-layer drain which was designed and built by Humboldt County forces consisted of a 0.33 ft and a 0.66 ft open-graded AC drainage layer. The locality and size of the project necessitated use of local materials. The filter material, therefore, contained more fines than would normally have been desirable but still fulfilled primary filter criteria. The drainage layer consisted of aggregate from the No. 4 (coarse) bin of an asphalt plant mixed with 2 percent of 85-100 penetration paving asphalt. The top lift of the asphalt treated drainage layer was uncompacted except for the compaction provided by the paving machine. After a one-day curing period, however, the surface could not be visibly deformed by the wheels of a loaded truck which graphically demonstrated the stabilizing effect of the asphalt. While a quantitative evaluation of the drainage capacity of the system was not attempted, several hundred gallons of water from a water truck applied to the surface of the asphalt treated drainage layer were absorbed immediately. A heavy flow from the cross drain pipe was noted within two to three minutes. This project thus provided a qualitative indication of the high capacity of a layered drainage system and, more importantly, indicated that construction would present no real problems.

Road 01-Hum-299

The apparently successful two-layer subsurface drainage system installed at Kneeland Road in Humboldt County and the availability of a suitable site was followed by the construction of a more extensive experimental test section by the Division of Highways in the fall of 1968 on Route 299 between Arcata and Willow Creek. The area selected for the test section was a through cut on a 6 percent grade. The roadway is an all paved two-lane facility with a truck climbing lane on the right. Grading had been completed with construction of the structural section and paving scheduled for 1969 or 1970.

One particularly attractive aspect of this location was the fact that it was to be constructed in its entirety by state day labor forces which permitted a high degree of flexibility and excellent control of construction with adequate time for the necessary instrumentation and evaluation.

The cut material consisted of crushed metashale and sandstone of the franciscan formation. Annual rainfall for the five year period 1963-1968 averaged 69.2 inches. Examination of the site in the spring of 1968 subsequent to completion of the cut revealed numerous springs (Figure 1), the largest of which was located at the cut bank on the uphill or left side of the roadway. The locations of active springs and moist spots visible on the prepared subgrade are shown by Figure 2, a plan of the experimental section.

The 600 ft experimental section was eventually divided into two subsections. From Sta. 485 to Sta. 489, the two-layer subdrain was installed consisting of 0.3 ft of standard Class 2 permeable material for filtration and 0.4 ft of asphalt treated permeable material for drainage. The control section (Sta. 489 to 491) consisted of a single layer of standard Class 2 permeable material, 0.7 ft thickness (See Figure 3). Eight-inch diameter PMP longitudinal collector pipes were placed along both shoulders. Based upon the results of laboratory permeability tests on the asphalt treated permeable material of several thousand feet per day reported by Lovering and Cedergren,[6] a rational design of the underdrainage system was considered unnecessary. The capacity of even 0.2 ft of uncontaminated asphalt treated permeable material was calculated to be up to 100 times greater than the seepage capacity of the basement soil even assuming a 5-ft head and a relatively high basement permeability value of 0.01 ft per day. Thus, 0.4 ft of asphalt treated permeable material was selected to allow for inevitable variations in thickness as a result of the construction operation and a certain amount of contamination by the filter material and the overlying aggregate subbase material. In a like manner, a 0.7 ft single drainage layer in the control section was selected simply to permit a direct comparison of the two systems.

Based upon a representative basement soil grading curve and the calculations shown by Figure 4, it was concluded that the standard Class 2 permeable material would serve satisfactorily as a filter for the two-layer system as well as for the single drainage layer for the control section. This dual use of Class 2 permeable material considerably simplified the construction operation.

Drainage materials were obtained from local commercial sources in the Arcata area, a distance of 25 miles. The gradings of individual Class 2 permeable material samples taken during construction superimposed upon the specification limits are presented by Figure 5. These plots show general compliance with specifications with a tendency to be slightly coarse in the No. 16 to 3/8-in. sieve sizes. The grading curves of samples taken subsequent to construction during the coring operation, are presented by Figure 6. They again show general compliance with one of the four samples on the fine side of the specification grading curve.

The aggregate used for the asphalt treated permeable material was a relatively uniform 3/4 in. to No. 4 size material as shown by Figures 7 and 8 which present grading curves of individual samples taken during and after construction. Significant breakdown did not occur as a result of the construction operation. The asphalt treated permeable material was plant mixed with the design asphalt content of two percent 85-100 penetration asphalt. Placement was made in two lifts of 0.2 ft each. The haul distance was 25 miles. Air temperatures ranged from 60 F to 74 F during placement. Upon delivery, mix temperature varied from 215 F to 250 F. No problems were encountered in putting the asphalt treated permeable material through the paver at these temperatures. The placement of the initial lift of asphalt treated permeable material over the Class 2 permeable filter blanket in its uncompacted state did present some difficulties due to the relatively clean cohesionless nature of the Class 2 permeable material. The tendency to rutting and displacement within the filter blanket required continual adjustment of the paver in order to maintain a relatively uniform thickness. Placement of the final asphalt treated permeable lift proceeded smoothly. As shown by Figure 9, displacement of the asphalt treated permeable material, shortly after placement, by loaded trucks was approximately 1/4 in. as compared to displacement up to 4 in. on the untreated permeable material. After initial set, no measurable displacement was observed in the asphalt treated permeable material by construction equipment. On future projects, it may be desirable to construct the filter layer utilizing permeable material of somewhat lesser quality, i.e., a higher percentage of fines and a greater compactive effort in order to construct a working table more suitable for the paving operation. As indicated by the filter criteria, calculations on Figure 4, basement soil conditions at this site would have permitted a much lower quality filter layer, since it need only be as permeable as the native soil to function effectively.

In order to obtain a field measurement of the relative drainage capacities of each subdrainage section, a series of six "artificial springs" were installed, three in each section. These devices consist of standard 2-in. pipe elbows welded to a steel base plate. To prevent clogging, the outlet ends were covered with a 200-mesh screen reinforced with a No. 4 screen. These units were then connected to 1 in. plastic tubing which was extended to the shoulder. In the roadway the tubing was buried in a small trench to prevent constriction by construction equipment. The outlet ends were placed directly at the bottom of the Class 2 permeable material layer. Photographs of the "artificial springs" and their installation are shown by Figure 11. The relative positions of these devices are shown schematically by Figure 3. Upon completion of the structural section in September, 1968, field permeability tests were run at each of the six test locations. At each location, a constant head was maintained with water being introduced into the structural section until a steady state flow condition was reached. At this point, the time required for the introduction of five gallons of water was recorded.

In the initial series of tests, several of the artificial springs were found to be inoperative. Efforts to unplug the malfunctioning devices included the probing of the 1 in. plastic tubing from the outlet and application of water under high pressure. Although these efforts appeared to be partially successful, two of the three springs installed in the two-layer system remained inoperable. Because it appeared that the malfunction was due to the clogging of the 200-mesh screen at the outlet end, a solution of nitric acid was introduced into all six systems. This technique successfully unplugged all springs.

Subsequent permeability tests revealed a relatively uniform capacity under 7 ft of head which led to the conclusion that the drainage capacity of both subdrain systems exceeded the capabilities of the artificial spring systems to introduce water. A valid comparison using these devices was therefore not possible.

Constant Head Field Permeability Tests

In a further attempt to measure the relative drainage capacities of the two subdrain systems, a constant head permeability apparatus of substantially higher capacity was designed and fabricated. The schematic diagram of the device and its installation is shown by Figure 12. Figure 13 is a photograph of an actual test installation.

The device consisted of an inner and outer casing differing in radius by 0.3 ft. The device was installed in the two-layer system by projecting the inner cylinder into the Class 2 permeable filter layer approximately an inch. The outer cylinder was placed directly on top of the filter material. The area between the two cylinders was effectively sealed with bentonite. The purpose of this arrangement was to insure that the water introduced into the two-layer system would be forced to travel a minimum of 0.3 ft through the Class 2 permeable material before reaching the asphalt treated drainage layer so as to permit a reasonable comparison between the two types of subdrains. In the control section, water was introduced into the Class 2 permeable material at mid layer. This test was carried out in the seven locations shown by Figure 2.

As with the artificial springs, water under a constant head was introduced at each test site until a steady state flow condition was reached. Thereafter, the quantity of water introduced into the system per unit of time was measured. The data resulting from these tests is presented in tabular form by Table 2. In the two-layer system, capacity ranged from 4.8 to 16.2 gallons per minute averaging 9.0 gallons per minute. In the control, or single-layer system, capacity ranged from 0.90 to 6.6 gallons per minute, averaging 2.8 gallons per minute. Based upon these figures, the two-layer system had a capacity of approximately 3.2 times that of the single-layer system. Disregarding the disproportionately high rate of 6.60 gallons per minute in the control section installation at Sta. 490+50, the capacity ratio increases to approximately 9.4 which probably more accurately reflects the real capacities of the two systems. Elimination of the high reading is probably justifiable by the fact that this location was within 4 ft of an artificial spring where the introduction of water under high pressures and the application of nitric acid may have disturbed the drainage characteristics in the immediate area.

The constant head test applied directly to the asphalt treated permeable material resulted in flows of 31.8 to 33.0 gallons per minute which indicated an in situ capacity of the asphalt treated permeable material of from 11.4 to 33.8 of that of the standard permeable material, depending upon the control section value selected for comparison.

Coring

In May, 1969, at the conclusion of an unusually wet winter and spring, seven locations on the experimental section were cored as shown by Figure 2. Of particular interest were the moisture contents of the various elements of the structural section in the previously mapped natural spring areas. In addition to moisture samples, bulk samples were taken for grading and laboratory permeability tests. At three locations, 8- by 8-in. chunks of the asphalt treated permeable material were removed for density measurements, asphalt content determination and laboratory permeability testing.

The results of laboratory tests on the recovered samples are shown by Table 3 and 4 and Figure 14. These data plus visual observations during coring operation indicate that both types of subdrainage systems functioned effectively through the winter and spring. A comparison of basement soil moisture contents, even in samples taken at the previously mapped spring areas, did not show a significant variation. Nothing approaching a saturated condition was observed. A possible reason for the effectiveness of both subdrainage systems is indicated by the results of a laboratory permeability test* on composite samples

*Calif. Test No. 220-B (Constant head permeability test) of the Class 2 permeable material shown by Figure 14. The laboratory specimen compacted to field density was found to have a permeability of 200 feet per day. Based on past experience, this is considered to be an unusually high permeability for this type of material, possibly due to careful handling, effective quality control, low degradability, and the absence of compaction by either rolling or traffic.

The results of laboratory permeability* tests on asphalt treated core specimens varied from 3000 to 22,000 feet per day. These values are not surprising based upon past observations and tests with this type of material. Examination of these cores revealed virtually no contamination by the underlying Class 2 permeable material or overlying Class 2 aggregate subbase.

Analysis of Data

Since one of the primary objectives of this project was a direct comparison of the drainage capacities of a conventional single-layer permeable blanket vs a two-layer system, a logical beginning requires a comparison of their capacities based upon theory. Applying Darcy's Law ($Q = kia$) it becomes readily apparent that, all other things being equal, the cross-sectional area of the Class 2 permeable material in either system is a controlling factor, since the permeability of the Class 2 material is many times less than that of the asphalt

*Calif. Test No. 220-B (Constant head permeability test) treated material and, in both systems, the drain water must pass through Class 2 material. In the case of the two-layer system, the drain water can pass upward through the underlying Class 2 permeable material layer into the asphalt treated layer to be quickly drained out through that layer at any spot under the surface of the roadway. Thus, the effective drainage area of Class 2 material in a two-layer system is the entire surface area of the roadway. If, however, one considers a single-layer system consisting of Class 2 permeable material, any drain water entering the permeable material must be carried all the way to the drainage outlet in that material. Thus, the effective area per unit length, instead of being the width of the roadway as in the two-layer case, becomes the thickness of the permeable layer. For the project under consideration, therefore, the theoretical relationship between the drainage capacities of the two systems would then be

$$\frac{16*}{0.7**} = 23.9$$

Based upon the limited data available from the constant head field permeability tests, the drainage capacity of the two-layer system was found to vary from 3 to 9 times that of the single-layer system. These values, while substantially less than that indicated by theory, still indicate a very substantial increase in drainage capacity through the utilization of the two-layer system.

*Half width of structural section (2-layer system)
**Thickness of permeable material (1-layer system)

A cost comparison of the two systems was not made since the project was not considered representative in terms of size and accessibility. In addition, overall thickness of both systems was the same which would not be the case had rational design criteria been employed. There is little doubt, however, that in terms of cost per unit of drainage capacity, the two-layer system would be the more economical by several orders of magnitude.

Summary and Conclusions

Because of the inconsistent performance of single-layer subsurface pavement drainage systems, the desirability of a two-layer system for highway construction has been recognized for several years. The stabilization of the drainage layer with one to two percent asphalt, appears to have eliminated the problem of excessive displacement in rutting of the drainage layer with placement of overlying elements of the structural section. The construction of a two-layer system utilizing an asphalt stabilized drainage layer on a portion of Kneeland Road in Humboldt County indicated that this type system has an unusually high drainage capacity and that it can be constructed with conventional equipment. The results of the experimental section on Route 299 which included both a two-layer drainage system using asphalt stabilized permeable material and a conventional one-layer system may be summarized as follows:

1. Both the single- and dual-layer systems were completely effective in removal of subsurface water during the unusually wet 1968-1969 winter and spring seasons.

2. The Class 2 permeable material which was used as the filter on the two-layer systems, and as the drainage element for the one-layer system, was found to be highly permeable as indicated by both field and laboratory tests.

3. Based upon theory, the two-layer system for this facility was approximately 24 times the capacity of the single-layer system.

4. The results of constant head field permeability tests revealed that the two-layer system had from 3 to 9 times the drainage capacity of the single-layer system. In a like manner, these tests indicated that the asphalt treated material was from 11 to 34 times as permeable as the standard Class 2 permeable material.

5. Placement of the asphalt treated permeable material over the filter layer was somewhat difficult as a result of rutting and displacement of the filter layer. These results indicate that an increase in the fines, the addition of water, and some compactive effort may be desirable for the construction of a two-layer system even at the cost of lower filter blanket permeability with the provision that filter criteria are still met.

7. In terms of cost per unit of drainage capacity, the two-layer system on the project was the more economical by several orders of magnitude.

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TABLE 1

DRAINAGE AGGREGATES USED BY THE CALIFORNIA DIVISION OF HIGHWAYS

Year of Std. Specs.	% Passing 6 in.	2-1/2 in.	2 in.	1-1/2 in.	3/4 in.	No. 4	No. 8	No. 30	No. 50	No. 200
1927	100				0					
1940	100				0					
1945		100			40-100	15-50	5-30	0-5		0-2
1949		100			40-100	15-50	5-30	0-5		0-2
1954 Type A					100	80-100	60-90	20-50	10-25	0-4
Type B				100	90-100	55-85	35-65	15-35	10-25	0-3
Type C		100		80-100	60-95	35-65	25-50	5-25		0-3
1960 Type A						90-100				
Type B				100	90-100	45-65				
Type C			100	90-100	60-80	40-60				
-No. 4						100	65-90	20-40	8-16	0-2
1964 & 1969 Cl. 1										
Type A					100	0-55	0-10			0-3
Type B			100	85-100	50-100	0-25	0-5			0-3
Cl. 2					90-100	25-40	18-33	5-15	0-7	0-3

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TABLE 2

CONSTANT HEAD FIELD PERMEABILITY TEST DATA

Station	Permeability gal/min Constant Head 43 Inches			Remarks
	Asph. Perm.	Two-Layer	Control	
485+65 ℄	-	7.20	-	
486+90 ℄	33.00	7.80	-	
487+90 ℄	31.80	16.20	-	Incomplete excavation thru asph. perm.
488+50 ℄	-	4.80	-	4 ft from artificial spring
489+40 ℄			*1.02	
489+85 ℄			*0.90	
490+50 ℄			6.60	4 ft from artificial spring - probably piping
Average	32.40	9.00	2.84	

*0.96 (average of low values)

TABLE 3

RESULTS OF THICKNESS, IN-PLACE MOISTURE AND DENSITY MEASUREMENTS

Core No.	Location	Depth (ft)	Material	Density (lb/ft^3)	Moisture Content (% Dry Wt.)
1*	15.5' rt. Sta. 488+50	0.37-1.29	Agg. Base	146.5	5.7
		1.29-1.70	Asph. Tr. P.M.	134	1.5
		1.70-2.02	Cl. 2 P.M.	126	2.8
		2.02-2.25	Basement Soil	-	10.5
2	10' rt. Sta. 490+00	0.38-1.36	Agg. Base	-	5.0
		1.36-2.21	Cl. 2 P.M.	-	3.2
		2.21-2.50	Basement Soil	-	9.1
3*	9' rt. Sta. 388+94	0.44-1.15	Agg. Base	-	5.4
		1.15-1.67	Asph. Tr. P.M.	131	1.3
		1.67-2.07	Cl. 2 P.M.	-	2.1
		2.07-2.35	Basement Soil	-	12.2
4*	18' rt. Sta. 486+67	0.37-1.37	Agg. Base	-	5.0
		1.37-1.73	Asph. Tr. P.M.	138	1.7
		1.73-1.89	Cl. 2 P.M.	-	2.9
		1.89-2.15	Basement Soil	-	11.8
5	℄ Sta. 488+50	0.40-1.34	Agg. Base	-	5.5
		1.34-1.81	Asph. Tr. P.M.	-	1.9
		1.81-2.05	Cl. 2 P.M.	-	2.6
		2.05-2.30	Basement Soil	-	10.6
6	4' lt. Sta. 489+60	0.37-1.38	Agg. Base	-	4.5
		1.38-2.08	Cl. 2 P.M.	-	2.3
		2.08-2.35	Basement Soil	-	13.8
7	℄ Sta. 486+04	0.35-1.60	Agg. Base	-	5.2
		1.60-1.87	Asph. Tr. P.M.	-	2.6
		1.87-2.13	Cl. 2 P.M.	-	2.7
		2.13-2.40	Basement Soil	-	12.3

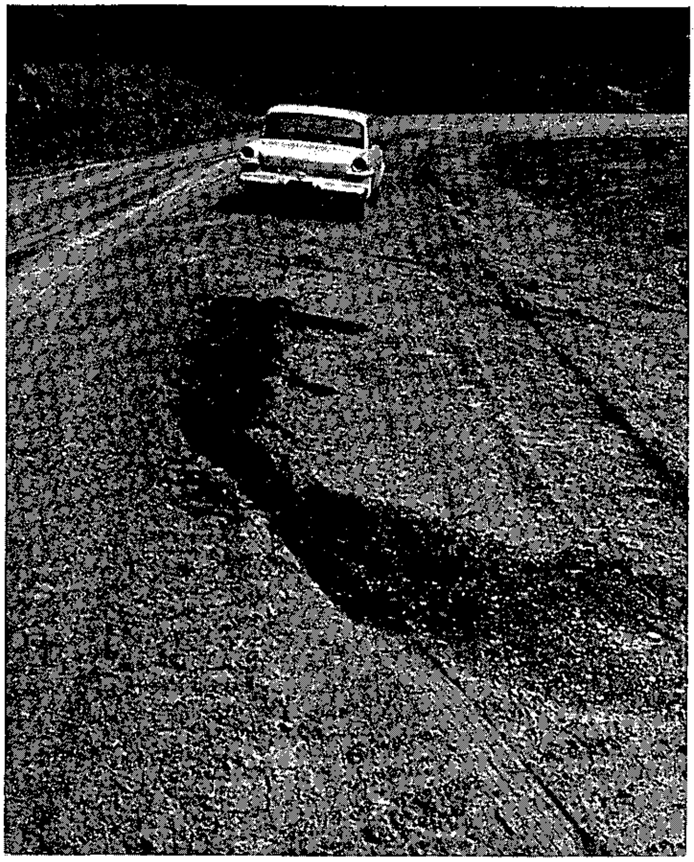
*Previously mapped spring areas

TABLE 4

RESULTS OF LABORATORY TESTS ON ASPHALT-TREATED PERMEABLE SAMPLES

Core No.	% Asphalt	Laboratory Permeability (ft/day)
1	2.1	3000
3	1.8	-
4	1.6	22,000

Figure 1

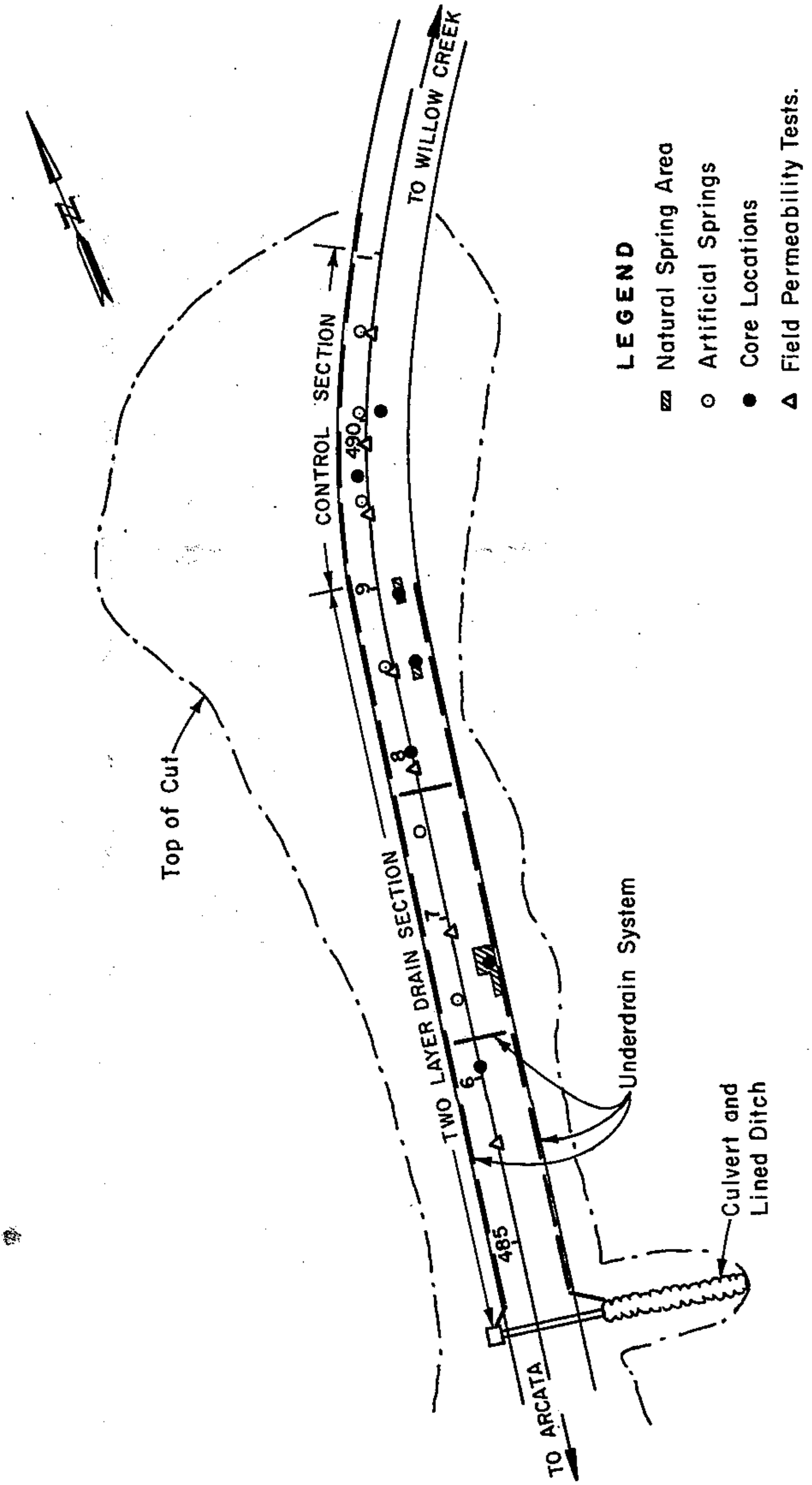


Natural Spring (wet area) in roadbed prior to paving.

Figure 2

EXPERIMENTAL DRAINAGE SECTION

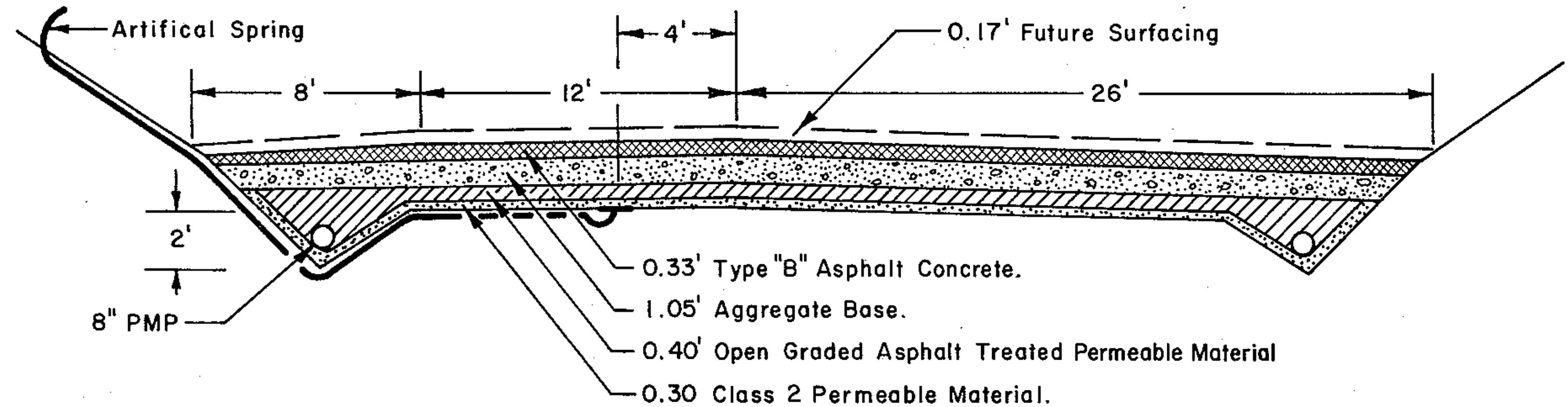
ROAD 01-Hum-299



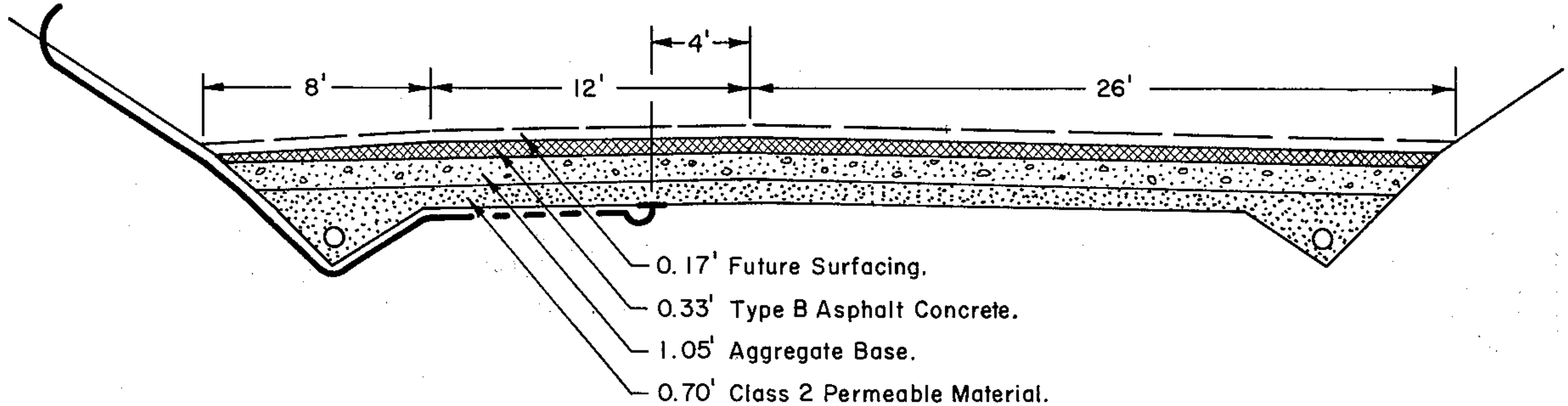
PLAN

Figure 3

TYPICAL SECTIONS



SECTION A - STAS 485-489
(A.C. PERMEABLE SECTION)



SECTION B - STAS 489-491
(CONTROL SECTION)

Figure 4

GRADING ANALYSIS OF NATIVE SOIL

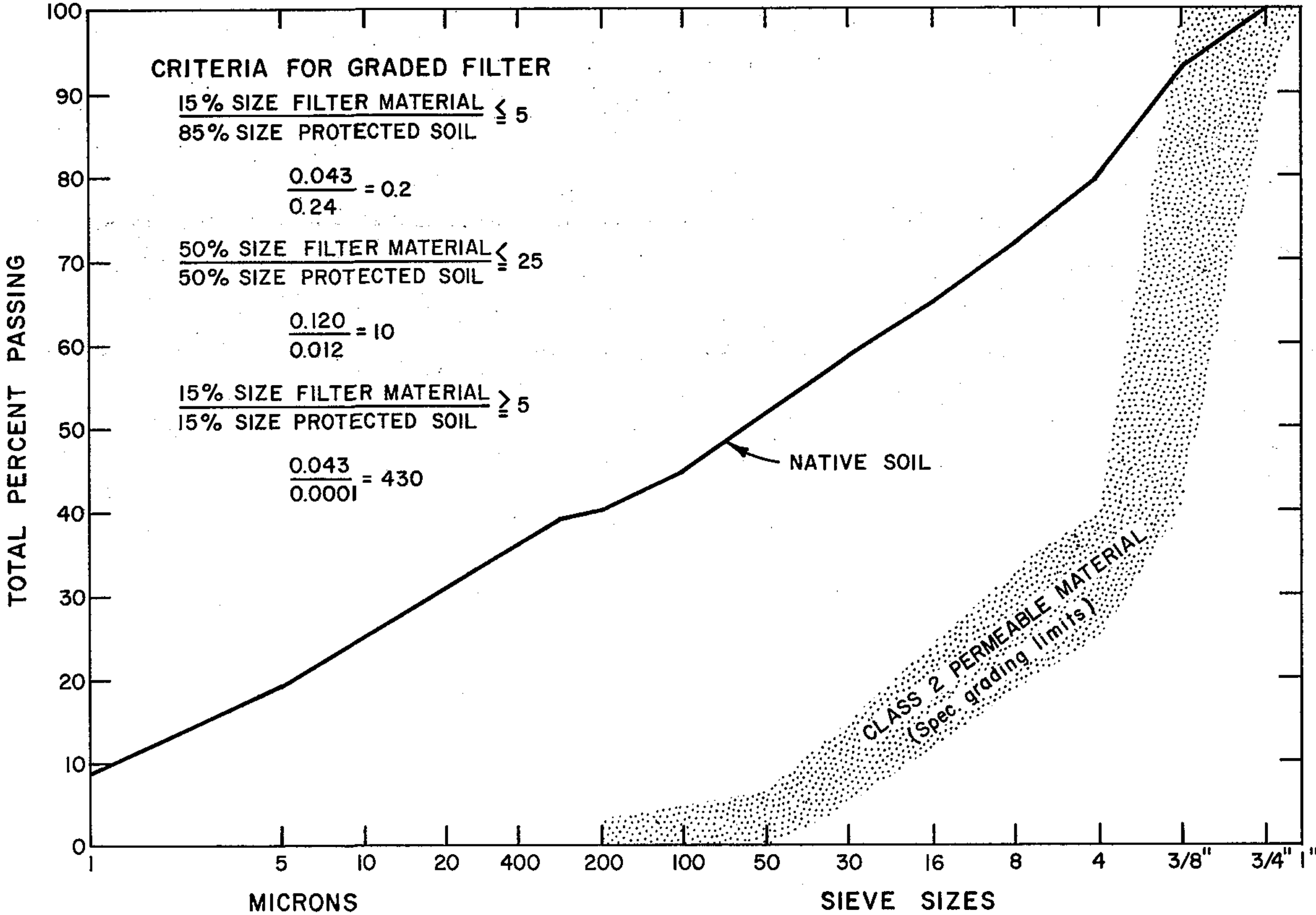


Figure 5

GRADING ANALYSIS

CLASS 2 PERMEABLE MATERIAL SAMPLED DURING CONSTRUCTION

Shaded area indicates specification limits

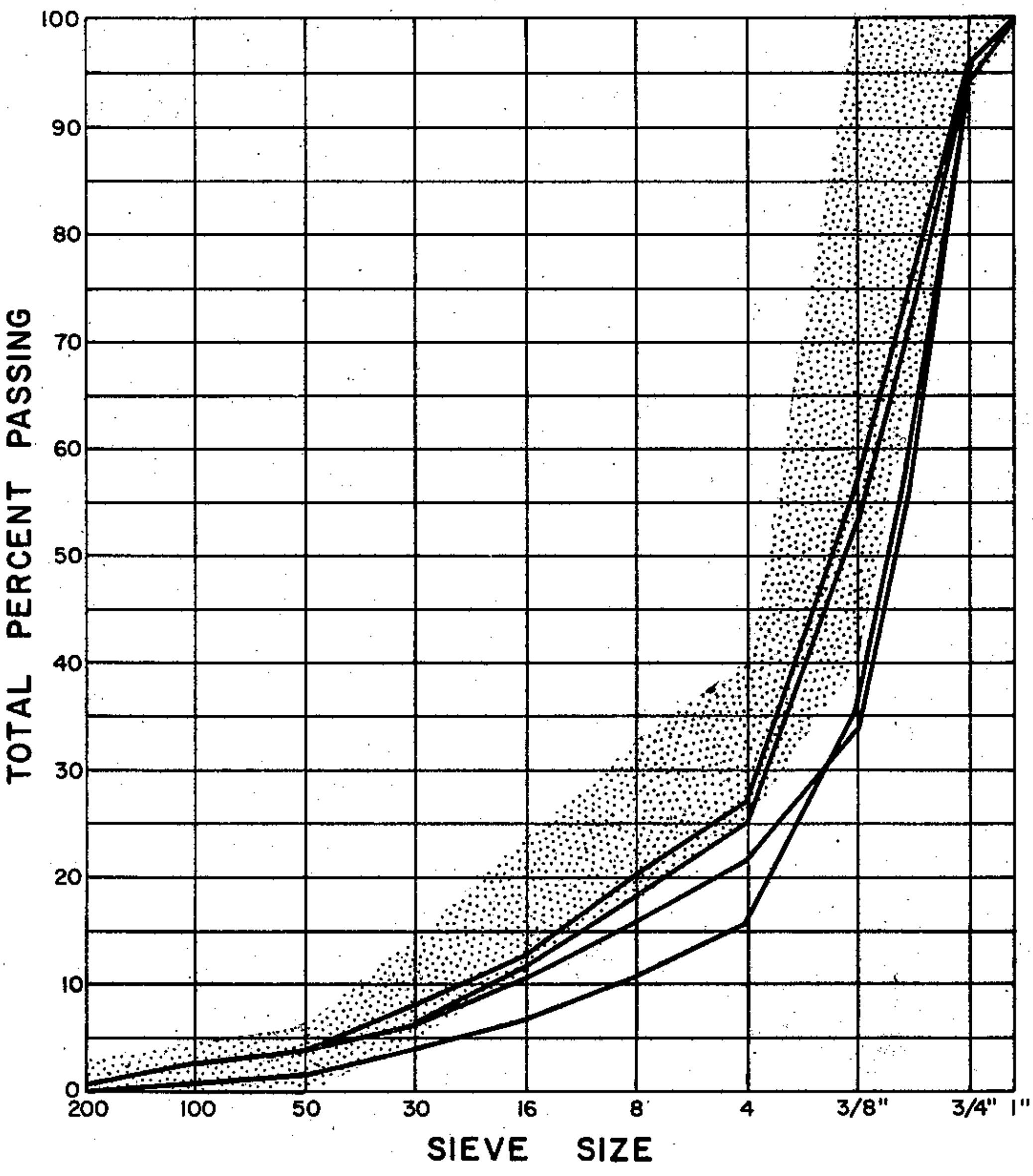


Figure 6

GRADING ANALYSIS

CLASS 2 PERMEABLE MATERIAL SAMPLED AFTER CONSTRUCTION

Shaded area indicates specification limits

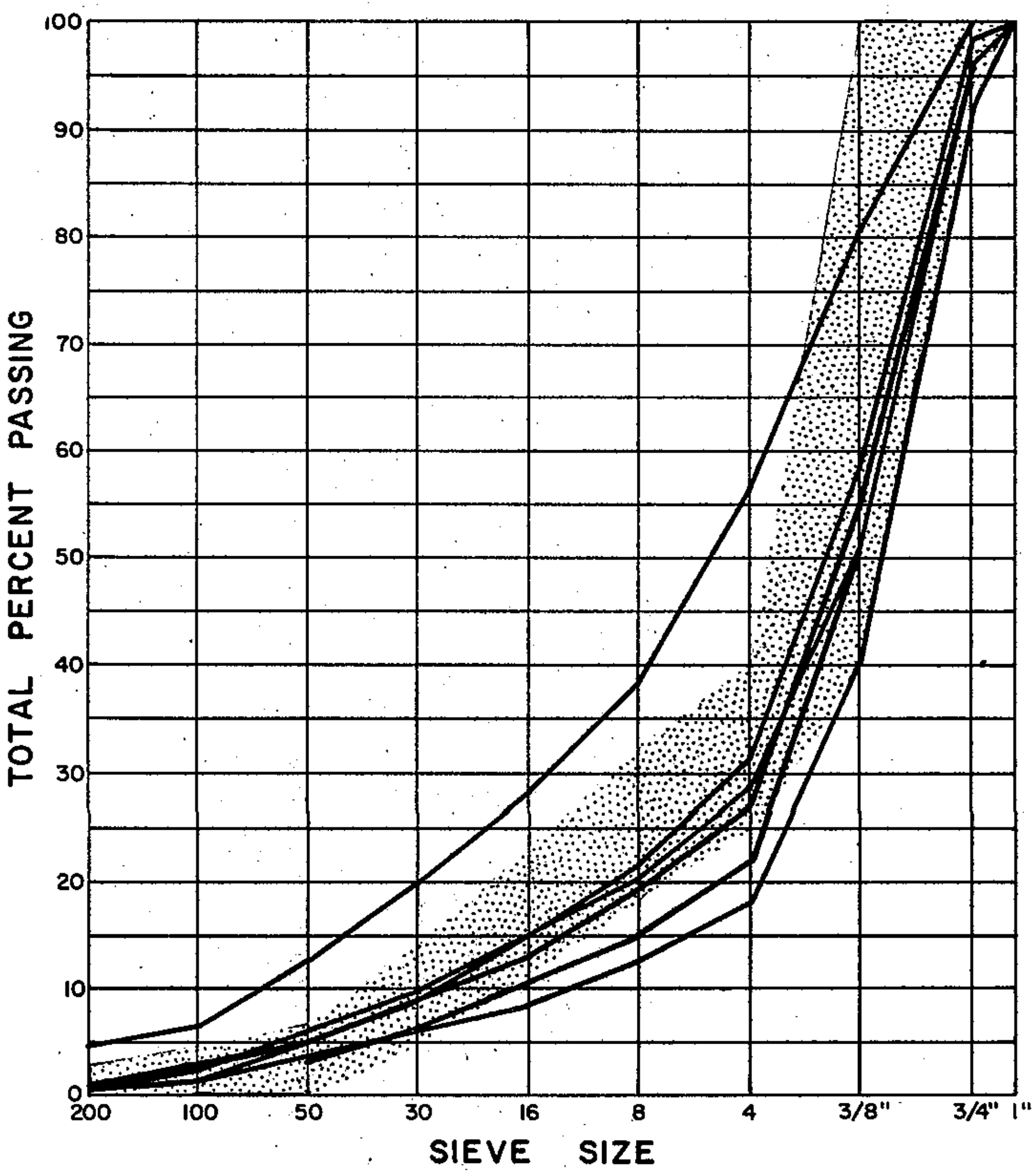


Figure 7

GRADING ANALYSIS

ASPHALT TREATED PERMEABLE MATERIAL SAMPLED DURING CONSTRUCTION

Shaded area indicates specification limits

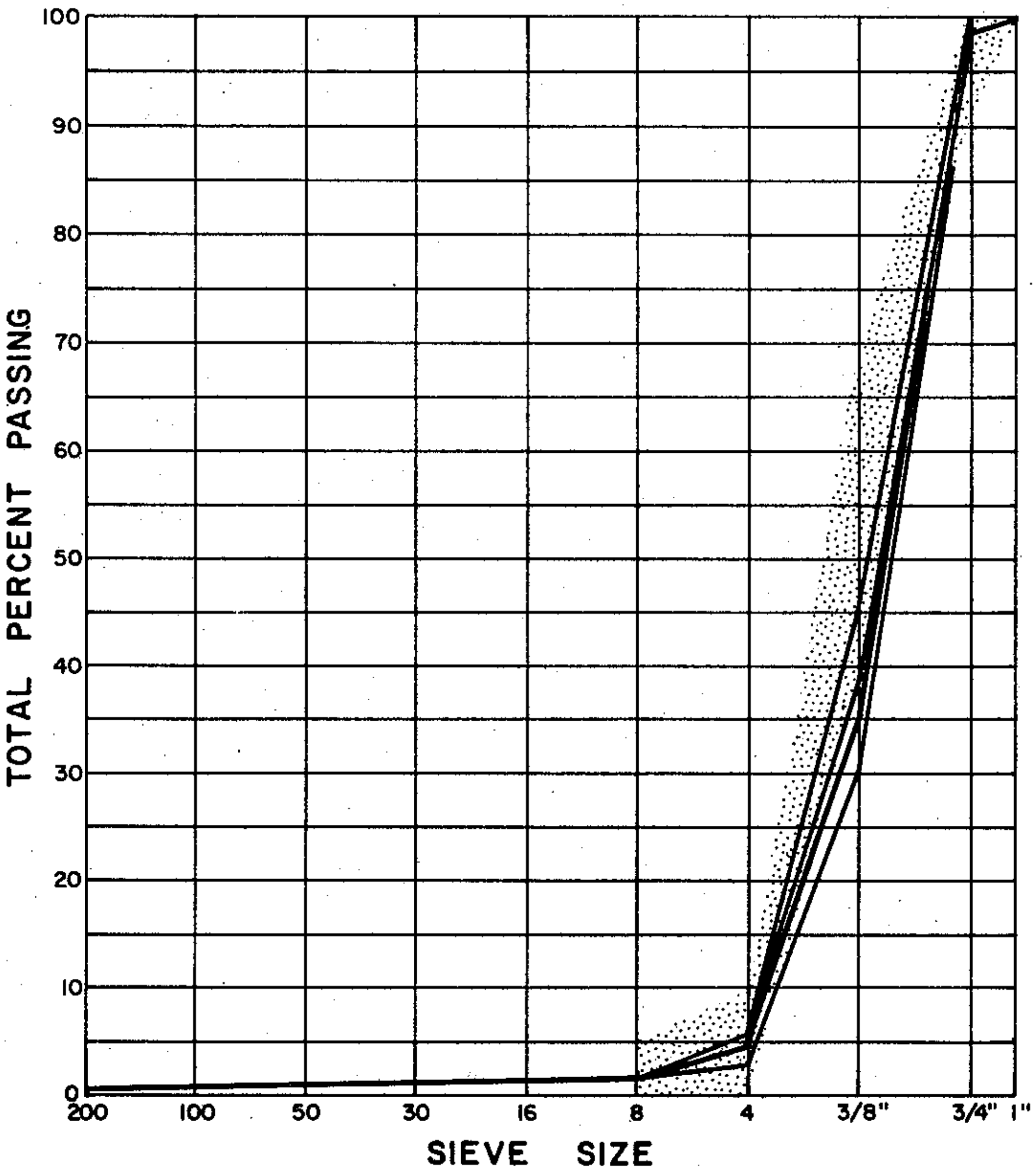


Figure 8

GRADING ANALYSIS

ASPHALT TREATED PERMEABLE MATERIAL SAMPLED AFTER CONSTRUCTION

Shaded area indicates specification limits

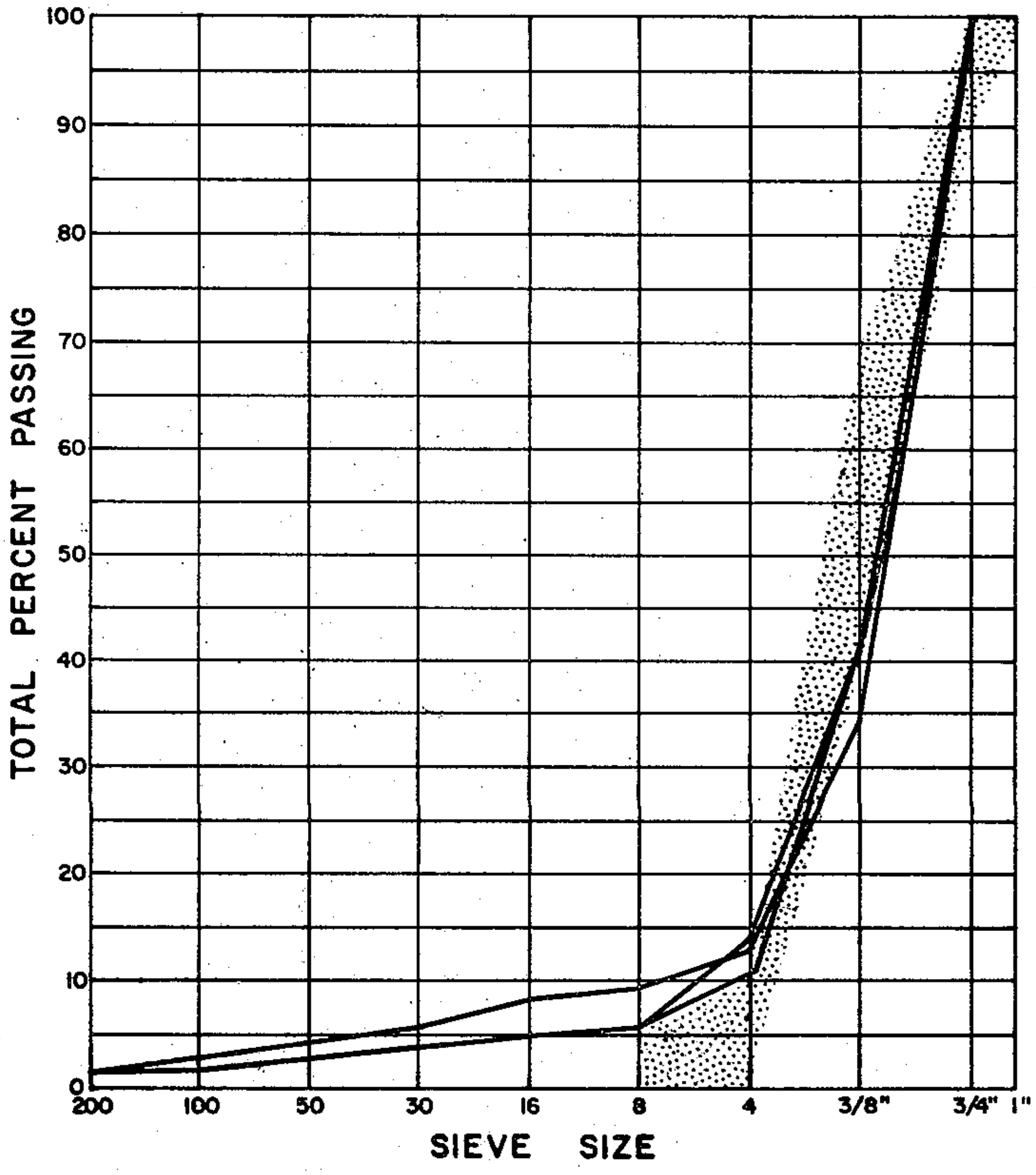
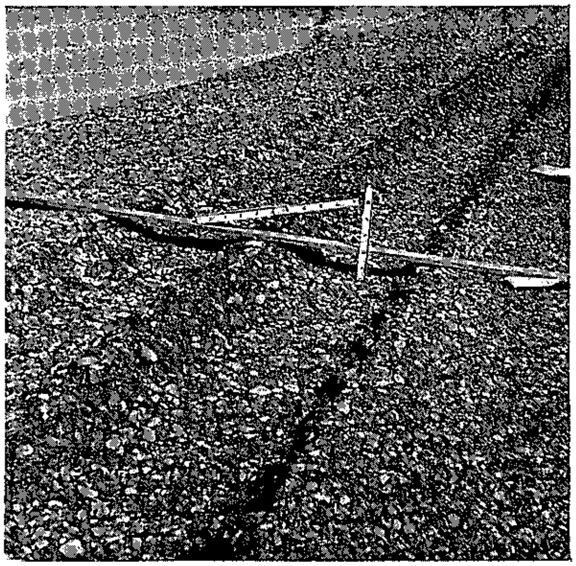
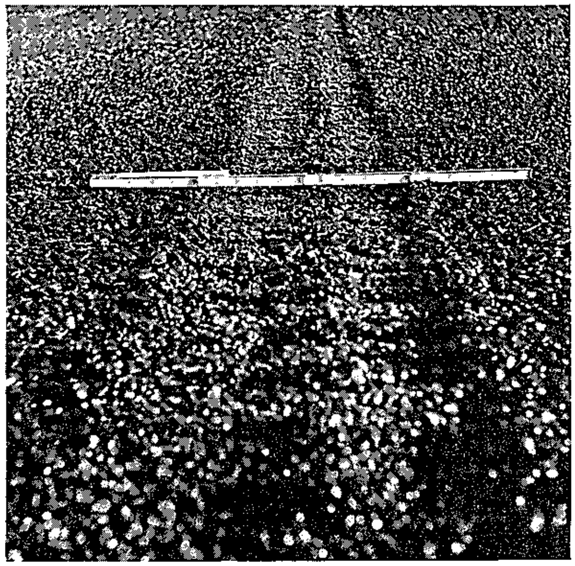


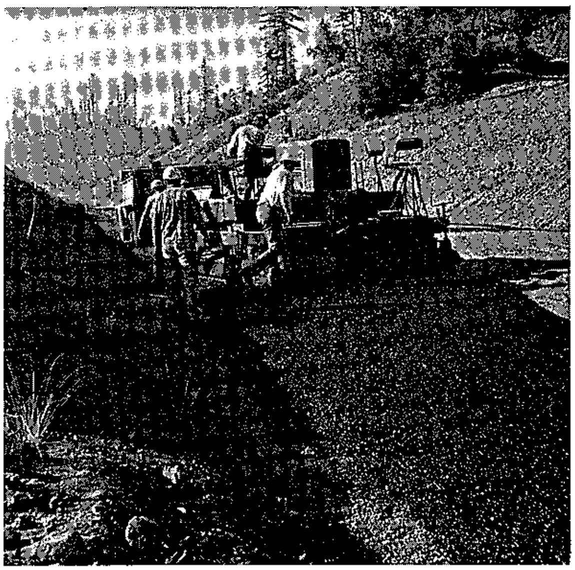
Figure 9





Wheel tracks in uncompacted permeable material (Class 2 permeable on left. Asphalt treated permeable on right) showing relative displacement under similarly loaded tracks.

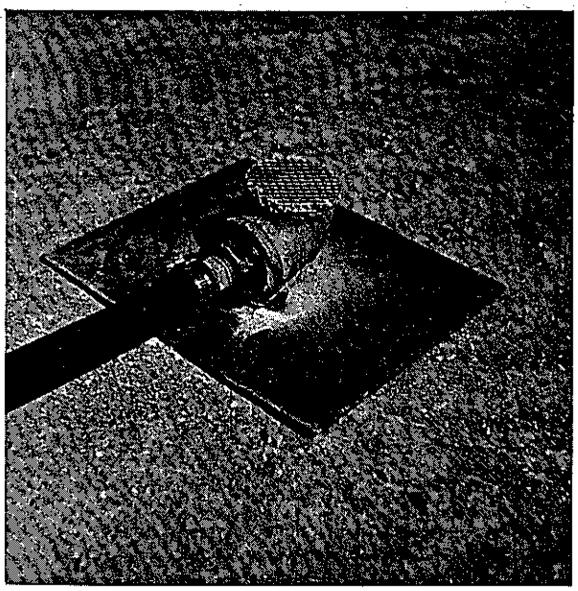
Figure 10



Placement of asphalt treated permeable material over Class 2 permeable material.

Placement of aggregate base on asphalt treated permeable material.

Figure 11



Artificial spring ready for installation

Installed artificial spring prior to covering.

Figure 12

CONSTANT HEAD FIELD PERMEABILITY TEST

No Scale

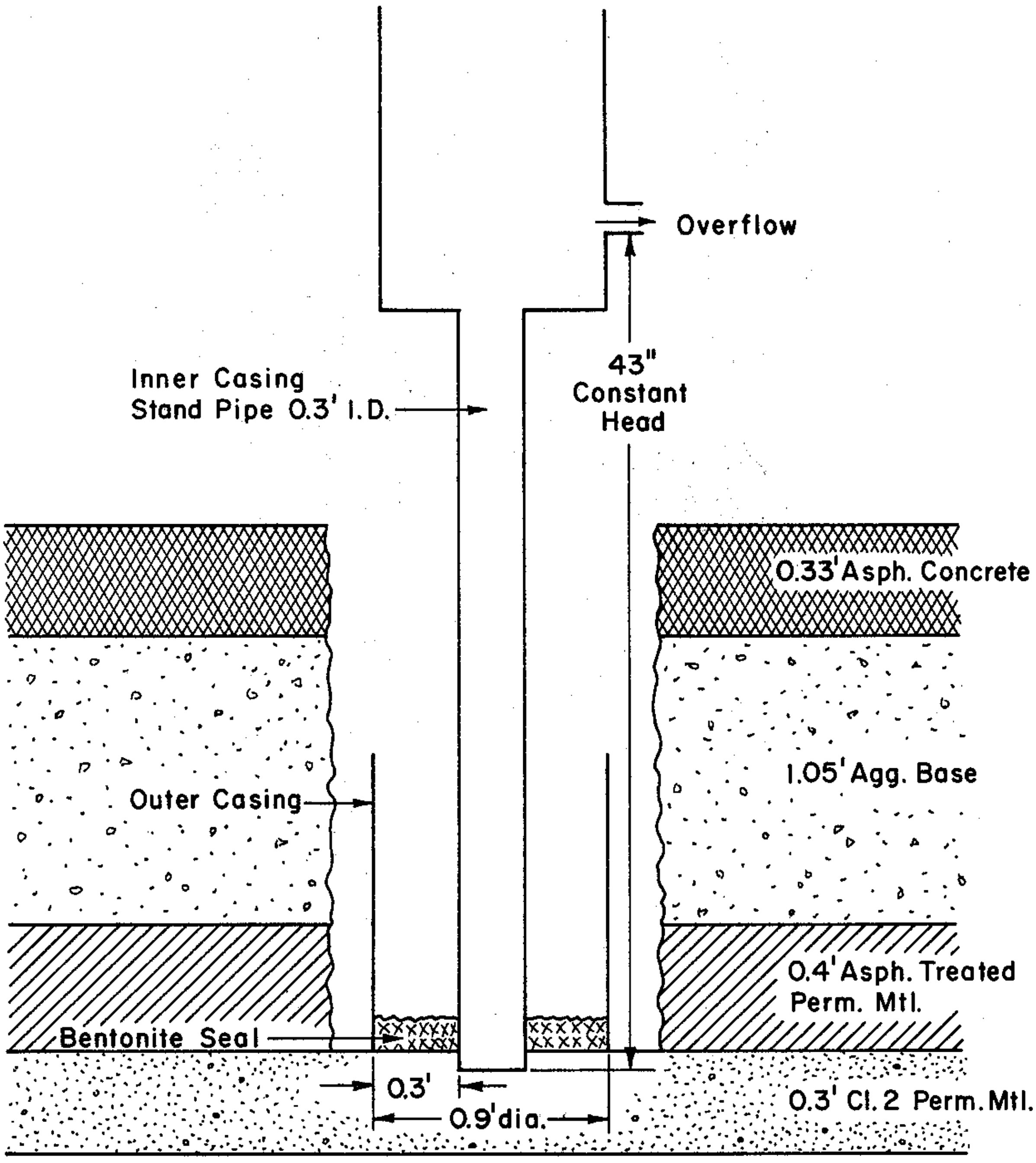


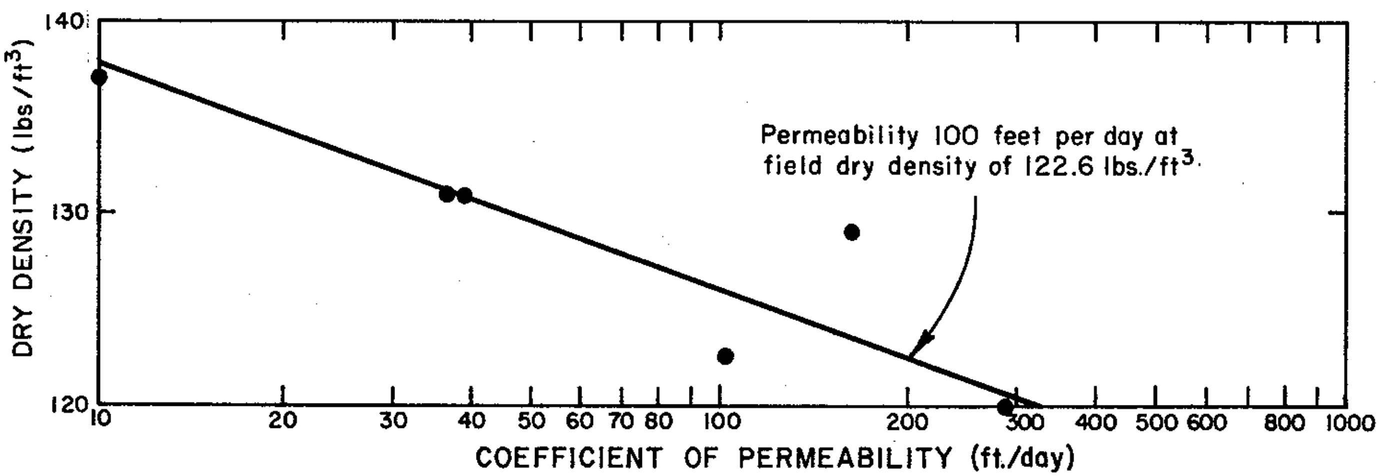
Figure 13

Field Permeability Test

Figure 14

RESULTS OF CONSTANT HEAD PERMEABILITY TEST
(CALIF. NO. 220B)

CLASS 2 PERMEABLE MATERIAL



~~Atwater Merced~~

~~Los Banos Rest I-5 N. Bound~~